

# Interconnecting Caribbean Electricity Grids: Examining the Possibilities

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5 May 2011

# Outline

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- Background
- Key Data on Select Caribbean Countries and Identification of the Most Viable Fuel Options per Country
- Multiple Grid Interconnections: Associated Issues and Considerations
- Proposed Regional Interconnection Projects and associated Considerations
- Defining the Way Forward – AIA
- Conclusions

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# BACKGROUND



## Background: Overview of Caribbean Electricity Grids

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- The current power generation market in the Caribbean consists nearly exclusively of regulated, vertically integrated utilities that sell electricity to end-use customers.
- Some IPPs and customer-level photovoltaic (PV) installations exist and sell to the local utility.
- Most countries are geographically small:
  - They have small power systems that require high reserve margins to provide satisfactory reliability.
- The main challenge faced by these utilities is high operating costs, driven by high fuel prices and diseconomies of scale.
- Inadequate tariff levels and a lack of appropriate regulations to promote innovation and efficiency exacerbate the problems.`

# Background: Overview of Caribbean Electricity Grids

## Similarities

- High dependency on fossil fuels - security of supply/ price volatility issues; environmental issues (e.g. climate change); electricity prices among the highest in the world.
- Due to the small size of the systems there are no economies of scale to be exploited.
- Higher prices for inputs as bulk purchase is limited.

## Differences

- Size of each individual island - area size, peak load, energy consumption, economic characteristics such as GDP per capita etc.
- Geographical differences , RE possibilities and differences in power system configuration (voltage level choice).
- Institutional differences - type of utility ownership and presence of regulatory bodies

The notable exception to most of the issues being faced by Caribbean countries is Trinidad and Tobago, owing to their abundant Natural gas reserves.

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# **Key Data/Statistics for Select Caribbean Countries and Identification of Viable Energy Options**

# Key Statistics on Select Caribbean Countries

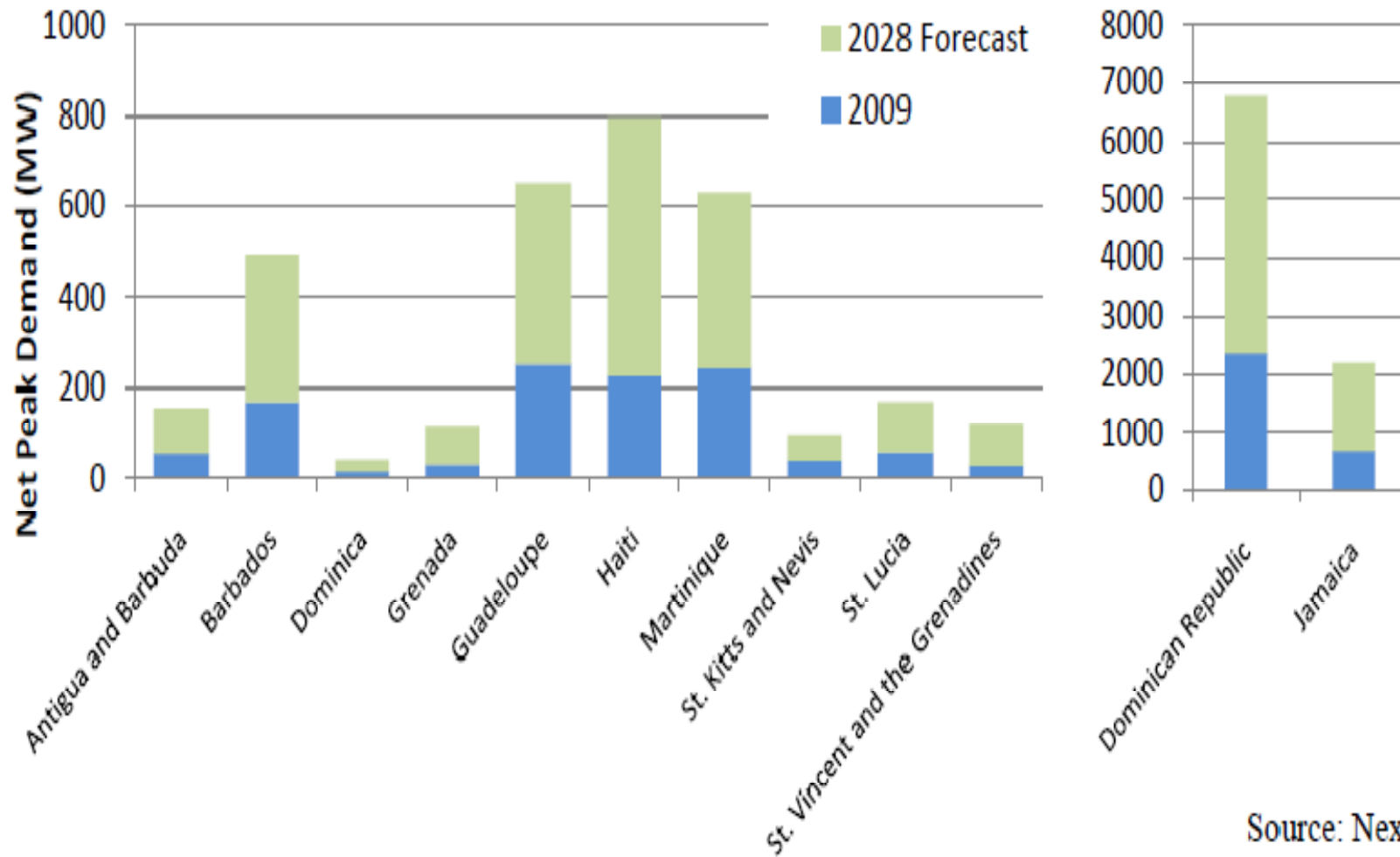
<b>COUNTRIES</b>	<b>Pop. (Million)</b>	<b>GDP (US\$B)</b>	<b>Installed Capacity (MW)</b>
Antigua	0.09	1.2	89.7
Barbados	0.29	3.4	242.0
Dominica	0.07	0.4	36.9
Dominican Republic	9.95	45.8	5518
Grenada	0.11	0.6	52.2
Guadeloupe	0.42	9.7	434.5
Haiti	9.72	7.0	226.0
Jamaica	2.69	15.1	932.2
Martinique	0.41	10.4	404.0
St. Kitts and Nevis	0.05	0.5	38.3
St. Lucia	0.17	1.0	77.2
St. Vincent	0.12	0.6	34.6
<b>TOTAL</b>	<b>24.09</b>	<b>95.7</b>	<b>8085.6</b>

## Current Fuels for Power Generation

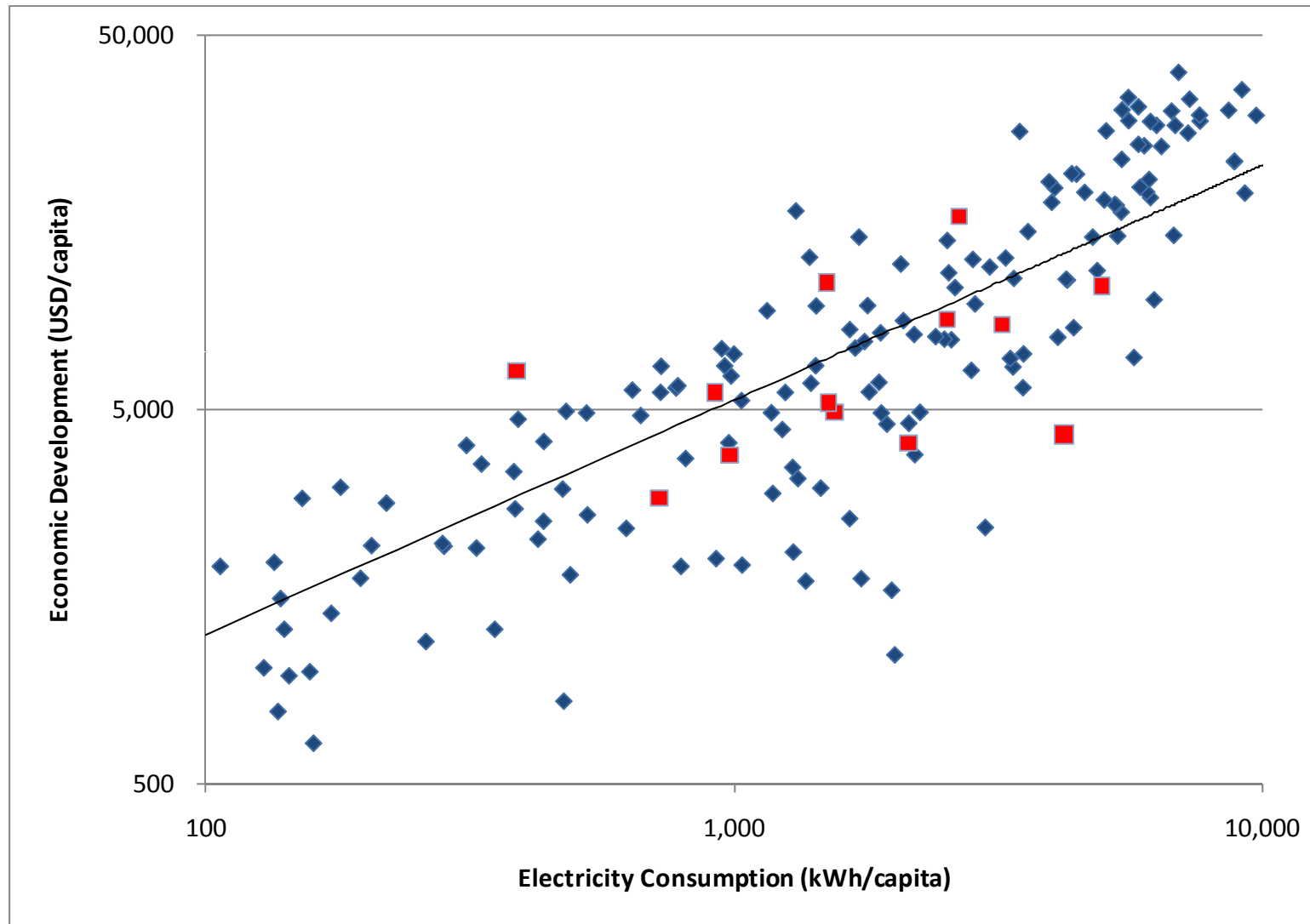
Country	Distillate	Heavy Fuel Oil	Natural Gas	Coal	Other
Antigua and Barbuda	X	X			
Barbados	X	X	X		Bagasse
Dominica	X				
Dominican Republic	X	X	X	X	20 percent hydro
Grenada	X				
Haiti	X	X			
Jamaica	X	X			Bagasse
Martinique	X	X			
Guadeloupe	X	X		X	Bagasse, geothermal and wind (4% each)
St. Kitts	X	X			
Nevis	X				
St. Lucia	X				
St. Vincent and the Grenadines	X	X			
Trinidad and Tobago			X		

Source: Nexant Report

# Peak Demand Load Forecasts 2009–2028 (MW)



# Electricity Consumption and Economic Development



Source: Kema 2010

## Estimates of RE Potentials within the Region

Table 8-13 Renewable Resource Estimate for the Caribbean Region

Resource	Wind		Geothermal		Hydro		Solar PV		Biomass		Total	
	MW	GWH/yr	MW	GWH/yr	MW	GWH/yr	MW	GWH/yr	MW	GWH/yr	MW	GWH/yr
Antigua and Barbuda	400	870		-		-	27	30		-	427	900
Barbados	10	20		-		-	26	30		-	36	50
Dominica		-	100	700	8	50	45	50		-	153	800
Dominican Republic	3,200	7,000		-	210	1,470	2,899	3,800		-	6309	12270
Grenada	11	20	400	2,800		-	21	20	0.5	2	432.5	2842
Guadeloupe	15	30	30	210		-	98	120		-	143	360
Haiti	10	20		-	50	350	1,654	2,170		-	1714	2540
Jamaica	70	150		-	22	150	650	850	40	210	782	1360
St. Kitts and Nevis	5	10	300	2,100		-	16	20	20	100	341	2230
St. Lucia		-	25	170		-	36	40		-	61	210
St. Vincent / Grenadines	2	4		-	5	30	23	30		-	30	64
Saba Island		-	400	2,800		-	-	-		-	400	2800
Total	3,773	8,224	1,255	8,780	295	2,050	5,803	7,560	61	312	11,187	26,926

- Source: Nexant 2010

## Viabable Future Options for Individual Countries

Country	Distillate	Coal	LNG	Wind	Geothermal	Hydro*	Biomass*
Antigua and Barbuda	✓	✓		✓			✓
Grenada	✓	✓		✓	✓		✓
St. Vincent and the Grenadines	✓	✓		✓		✓	✓
St. Kitts	✓			✓			✓
St. Lucia	✓	✓		✓			✓
Dominica	✓			✓	✓	✓	✓
Nevis	✓			✓	✓		✓
Barbados	✓	✓	✓	✓		✓	✓
Guadeloupe	✓	✓	✓	✓	✓		✓
Martinique	✓	✓	✓	✓	✓		✓
Haiti	✓	✓	✓	✓		✓	✓
Jamaica	✓	✓	✓	✓		✓	✓
Dominican Republic	✓	✓	✓	✓		✓	✓

✓ = viable option

\* The resources are site specific and need to be studied further.

## Natural Disasters impacting the Region

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# Multiple Grid Interconnections and Associated Issues

## Basic features of an Grid Interconnections

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- The basic design features of an interconnection include the following elements:
  - Technical Aspects of Grid Interconnection
  - whether it is AC or DC (if DC, whether it is single-pole or double-pole (+/-))
  - transmission capacity (in MVA)
  - transmission voltage (in kV)
  - system components and overall design
  - operating agreement

## Multiple Grid Interconnections

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- Multiple Grid interconnections can be as modest as the one-way transfer of a small amount of electricity from one country to another, or as ambitious as the full integration of the power systems and markets of all of the countries in a region.
- Whatever the scale, these interconnections can help to:
  - contribute toward the process of sustainable development.
  - help to increase the supply and/or reliability of electricity for use in education, employment generation, health care, and many other development related activities, and
  - can contribute toward the formation of competitive markets for electricity on national and regional scales, helping to potentially reduce the cost of electricity to developing economies.
- Multiple grid interconnections are often, however, extremely complex undertakings, with technical, economic, legal, political, social, and environmental issues—costs, benefits, and considerations—that must be taken carefully into account before and as arrangements for power sharing are made.

# Potential Benefits of Grid Interconnections

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## Technical:

Improving reliability and pooling reserves; Improving load factor and increasing load diversity grid, stability benefits, diversification of generation mix and security of supply.

## Economic:

Avoided Fuel Costs, Avoided Generation capacity costs, Avoided operating costs, income from power sales, stimulation of local economies.

## Legal:

Establishing cross-border legal standards

## Political:

Spur additional international Cooperation, force for avoidance of conflict, and positive impact on political stability

## Social:

Benefits relate to improvement in society owing to improved electricity supply, electricity-related income and savings, ancillary benefits of construction and other activities & capacity building in key areas.

## Environmental:

Reduced or avoided air pollutant emissions, reduced water pollution, solid and hazardous wastes, land-use impacts, impacts on biodiversity and wildlife, and impacts on human health

# Multiple Grid interconnections: Factors to Consider

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## Technical

- Grid stability benefits.
- Potential costs in the form of impacts on grid of technical problems in an interconnected network.
- Considerations in transferring power between grids with different technical standards of power quality and reliability.

## Economic

- Benefits in the form of avoided fuel, capacity, and operating requirements for one or more countries (for example, through taking advantage of economies of scale).
- Costs in the form of required payments for transmission infrastructure.
- Considerations such as deciding on electricity pricing, national contributions toward interconnection costs, and the impact of power from interconnections on local economies.

## Legal

- Benefits in the form of model legal standards for cooperative activities of all types.
- Costs such as the need to adapt National laws and practices to regional/international standards.
- Complications such as determining jurisdictions for settling disputes, deciding on protocols for selecting contractors, and determining liability for third-party injuries due to activities related to the power line.

# Multiple Grid interconnections: Factors to Consider

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## Political

- Benefits such as increasing cooperation and understanding between governments linked by the interconnections.
- Liabilities such as additional exposure to potential political instabilities in a neighboring country.
- Considerations such as existing political rivalries between would-be electricity trading partners.

## Social

- Benefits in the form of improved access to electricity for development-related activities.
- Potential costs in the form, for example, of intrusion of power lines into traditional areas used by indigenous peoples.
- Considerations such as providing opportunities for all affected social groups to provide input into the interconnection planning process.

## Environmental

- Potential benefits such as avoided greenhouse gas, regional and local air pollution.
- Possible costs such as the impacts of power lines on animal populations.
- Considerations such as compliance with local and international regulations and protocols, and coordination in operation of grid interconnections so as to maximize environmental benefits.

# Interconnected Grid Systems: Submarine cabling bringing it all together

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## Types of Cables

- Power cable systems can be organized into three general categories, namely: Self-contained cables; Pipe-type cables; Gas insulated lines
- Only self-contained cables are generally used in submarine cable applications. Power transmission can be via DC or AC cables.

## Depth

- Depth limitations are of special interest in the Caribbean, which generally is deep and has numerous deep trenches. Depth limitations are mainly concerned with cable mass in relation to the tensile strength of the cable.
- As a guideline, the maximum depth for AC cables is 1,000 m, whereas for DC cables it is 1,500 m.

## Strength

- In order to lay or retrieve a cable for repair, the strength of the cable material must be sufficient to support the weight of the length of the cable between the ocean floor and the surface (less its buoyancy).
- In other words, a cable cannot be placed at greater depths than its strength can support.

# AC or DC Cables

## DC CABLES

Can transmit power, without frequency considerations .

This will, however require the end-user to have an inverter/converter.

The high cost of converter stations for DC cables makes them uncompetitive for short distances

Power transfer requirement is greater than 150–300 MW and Long length (typically  $\geq 25$  miles) interconnection

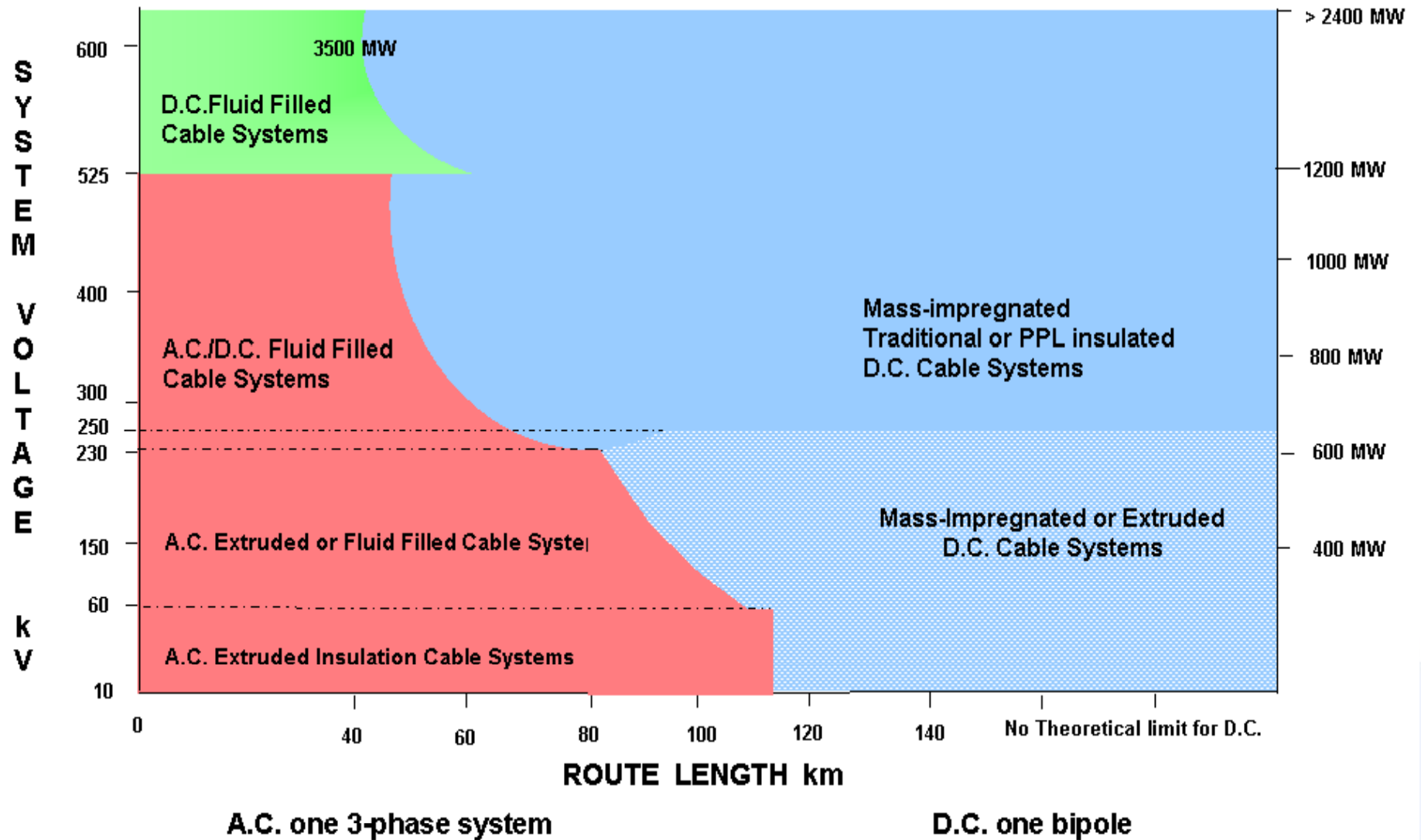
## AC CABLES

First requirement is that the systems share the same nominal frequency, either 50 Hz or 60 Hz. They must also interconnect at a common voltage level.

AC cables are not used for long distances because the capacitance charging current increases linearly with length and eventually consumes all of the available real current rating

Long-distance AC transmission has inherent stability limit. This can be extended through reactive compensation.

# Transmission Cable System Selection Criteria for Various Cable Types and Capacities



# Submarine Cables – Possible Issues & Mitigating Measures

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## Possible Issues & Impacts

- Cable-laying temporarily disturbs seabed habitats
  - As far as the construction phase (i.e. the placement) of cables is concerned, the associated impacts (disturbance, habitat damage) are generally not likely to be detrimental because they are mostly local and temporary.
- The main long-term impact of submarine cables is the presence of the cable itself and any accompanying protective structures. These can provide artificial hard substrate habitats that attract flora and fauna that may not be typical of the area. Again, since it is confined to the cable route itself, such change is not likely to be significant.
- Operational power cables may disturb electromagnetically sensitive or temperature-adapted species.

## Minimizing the Impacts

- Available measures to minimise or even avoid most of the anticipated environmental impacts include careful routing and scheduling of installation activities, suitable choice of cable types, appropriate burial of the cable and use of inert material if protective cover is necessary.
- In addition:
  - Further scientific investigations into the environmental impacts of the placement and operation of cables should be conducted in order to close existing gaps in knowledge.
  - Common guidelines for the placement of submarine cables should be developed
  - Common guidance on environmental considerations for the placement and operation of submarine cables should be developed.

# Grid Interconnection: Issues and Challenges

## Technology

Interconnections obviously entail the expense of constructing and operating transmission lines and substations, or in the case of HVDC, converter stations. Interconnections also entail other costs, technical complexities, and risks:

For AC interconnections especially, a power system interconnection is a kind of marriage, because two systems become one in an important way when they operate in synchronism. To do this requires a high degree of technical compatibility and operational coordination, which grows in cost and complexity with the scale and inherent differences of the systems involved.

## Standards

Within countries, there are typically common technical standards for all utilities, which reduces the complexity of interconnecting separate systems.

In different countries, on the other hand, power systems may have evolved quite separately, with very different standards and technologies, which adds an extra layer of technical complexity to interconnections.

## Policy & Institutional Arrangements

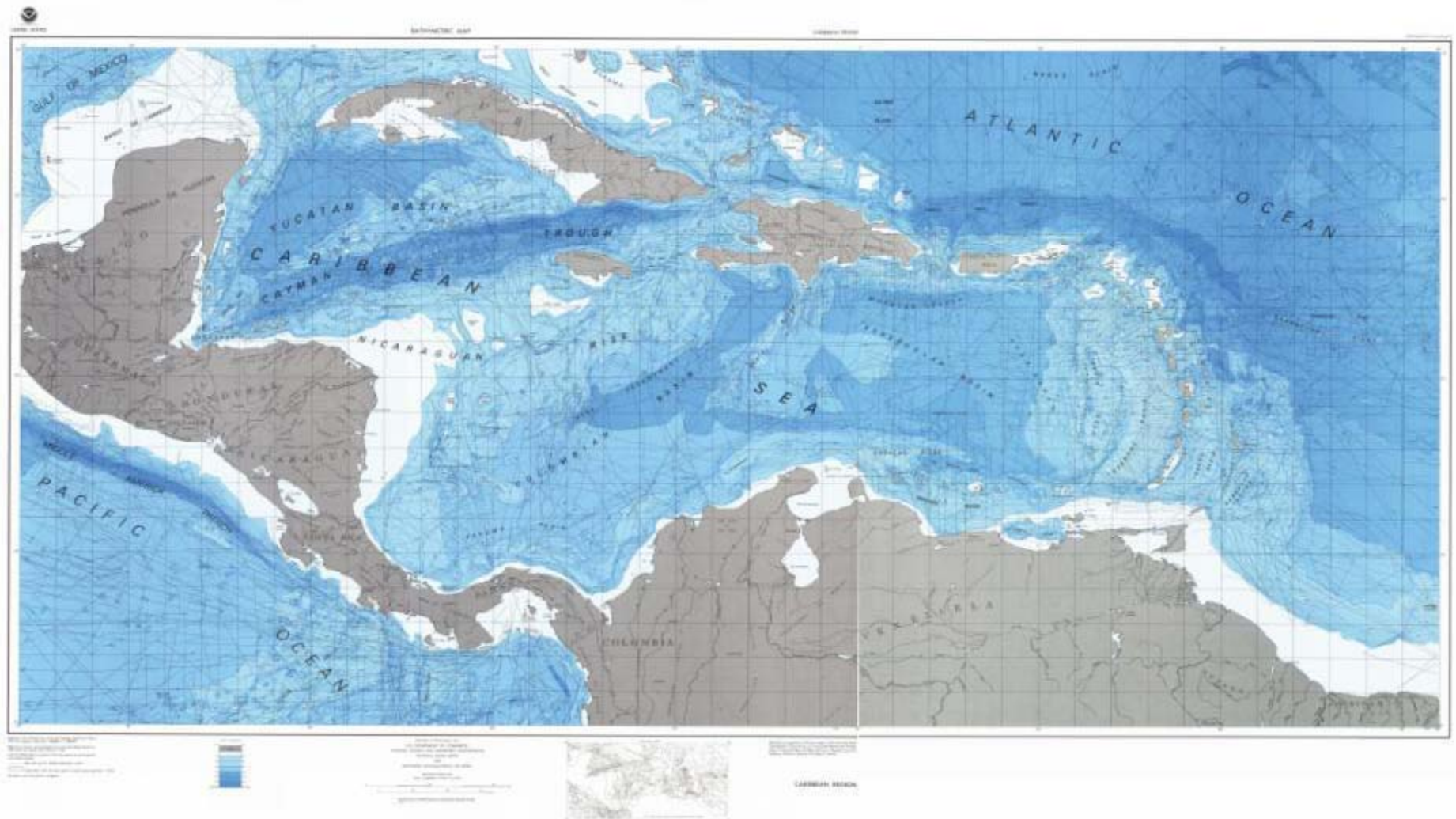
Institutional and administrative features of power systems in different countries are also likely to differ in many ways, and these differences invariably affect the technical and operational dimensions of an interconnection.

Issues ranging from power trading agreements to reliability standards, while expressed in technical terms, often must be resolved within the realm of policy and political economy.

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# Proposed Regional Interconnection Projects and Associated Considerations

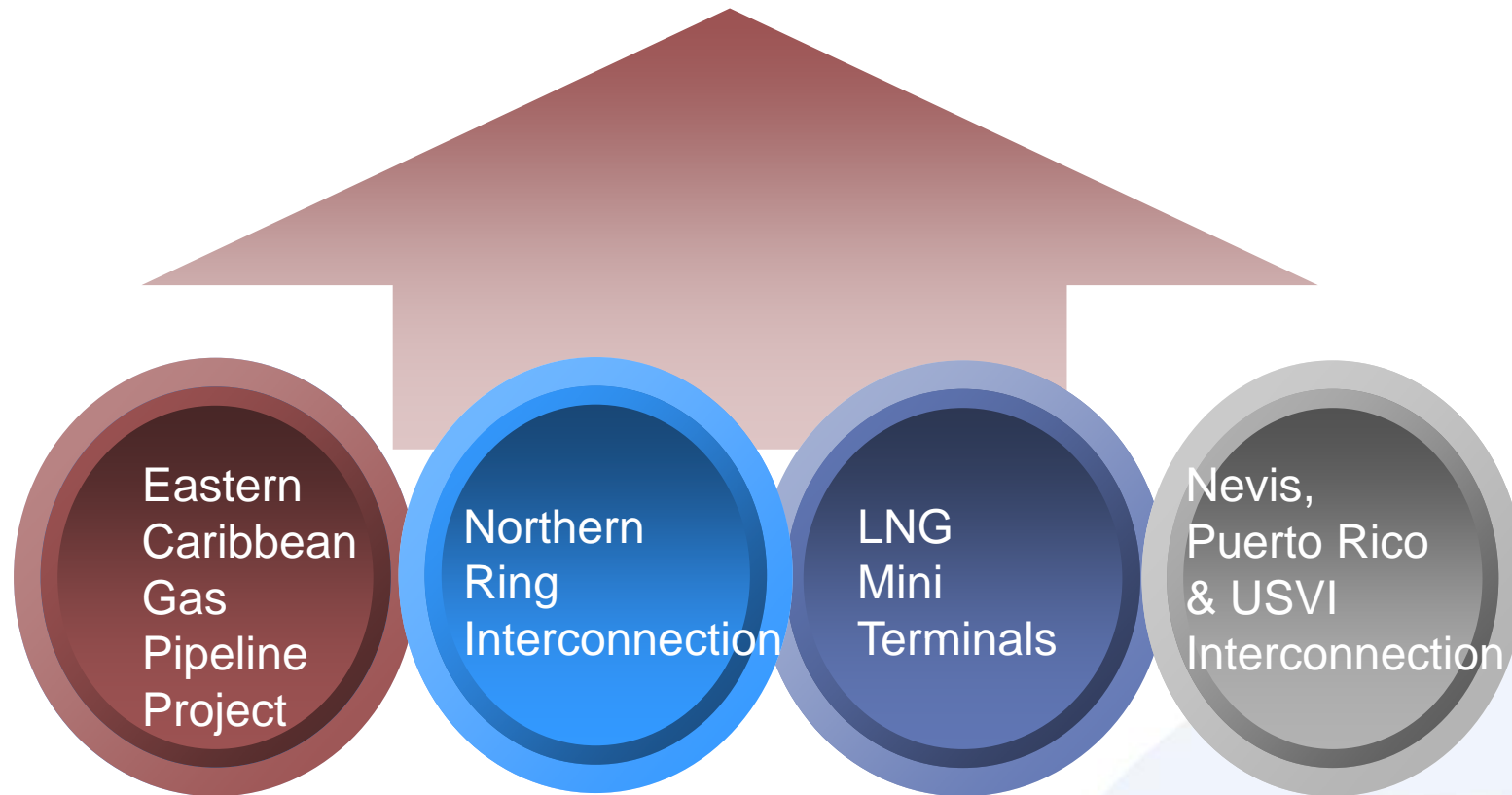
# Caribbean Bathymetric Information



# Proposed Regional Interconnection Projects

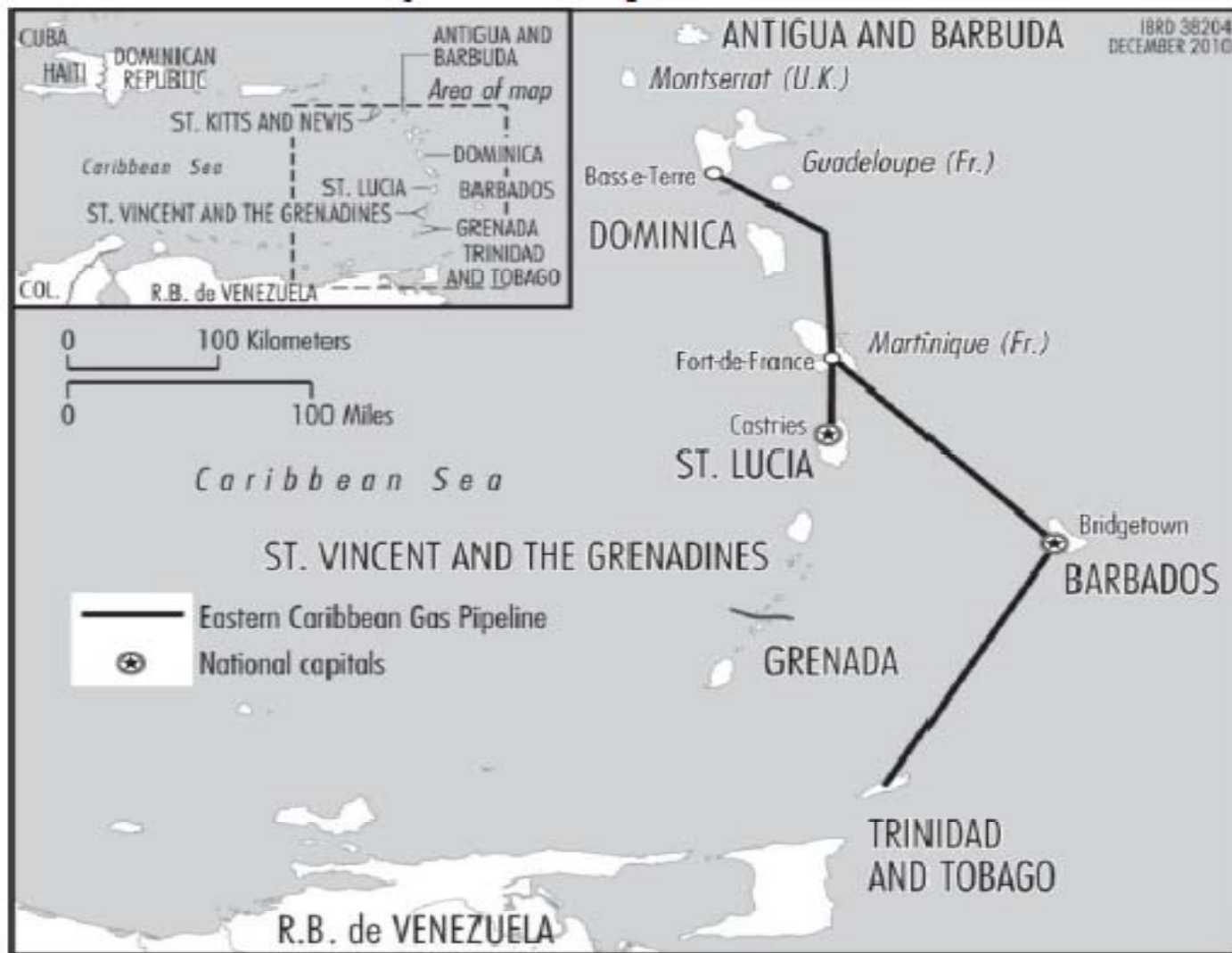
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## Proposed Projects



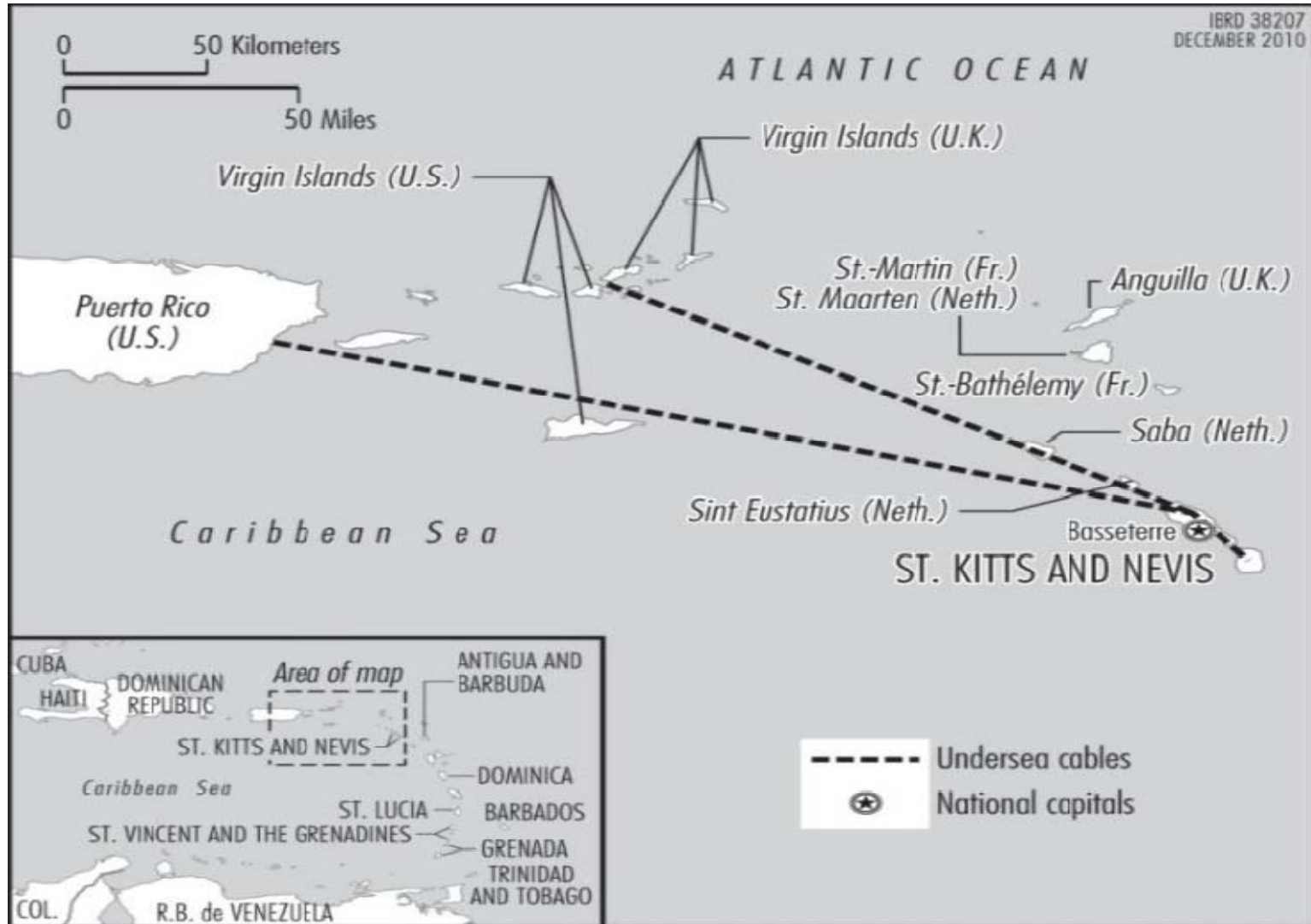
Existing Studies: World Bank Report (Nexant), 2010, world

# The Eastern Caribbean Gas Pipeline Project



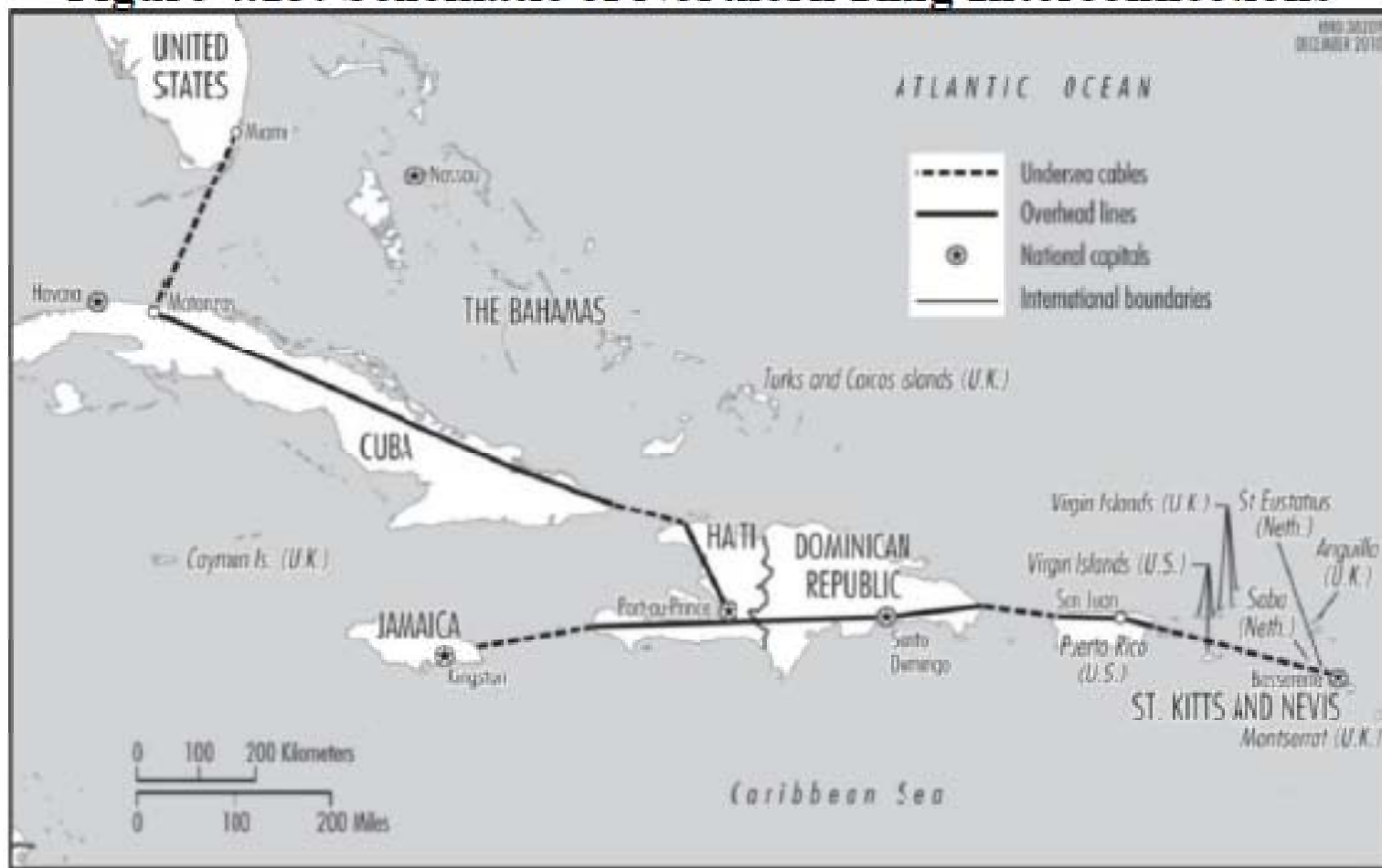
Source: Caribbean Regional Electricity Supply Options: Toward Greater Security, Renewables and Resilience – World Bank, 2011

# Nevis, Puerto Rico and US Virgin Islands Interconnections



Source: Caribbean Regional Electricity Supply Options: Toward Greater Security, Renewables and Resilience – World Bank, 2011

# Northern Ring Interconnection



Source: Caribbean Regional Electricity Supply Options: Toward Greater Security, Renewables and Resilience – World Bank, 2011

## LNG Mini Terminals

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- San Felipe is a 180 MW plant located in the north of the Dominican Republic for which a fuel switch to LNG is being proposed.
- In order for that to happen:
  - The LNG needs to be sourced from Trinidad.
  - If from Trinidad, presently there is not a loading facility for small LNG vessels there.
  - To justify the small vessel loading facility at Atlantic LNG, regular small volumes are required.
  - It is believed that San Felipe has enough volume to make the operation feasible, however there is a need for more, specifically from other regional utilities in a similar situation in order to guarantee the required volumes.

## Proposed Interconnection Projects: Issues/Areas to be Resolved

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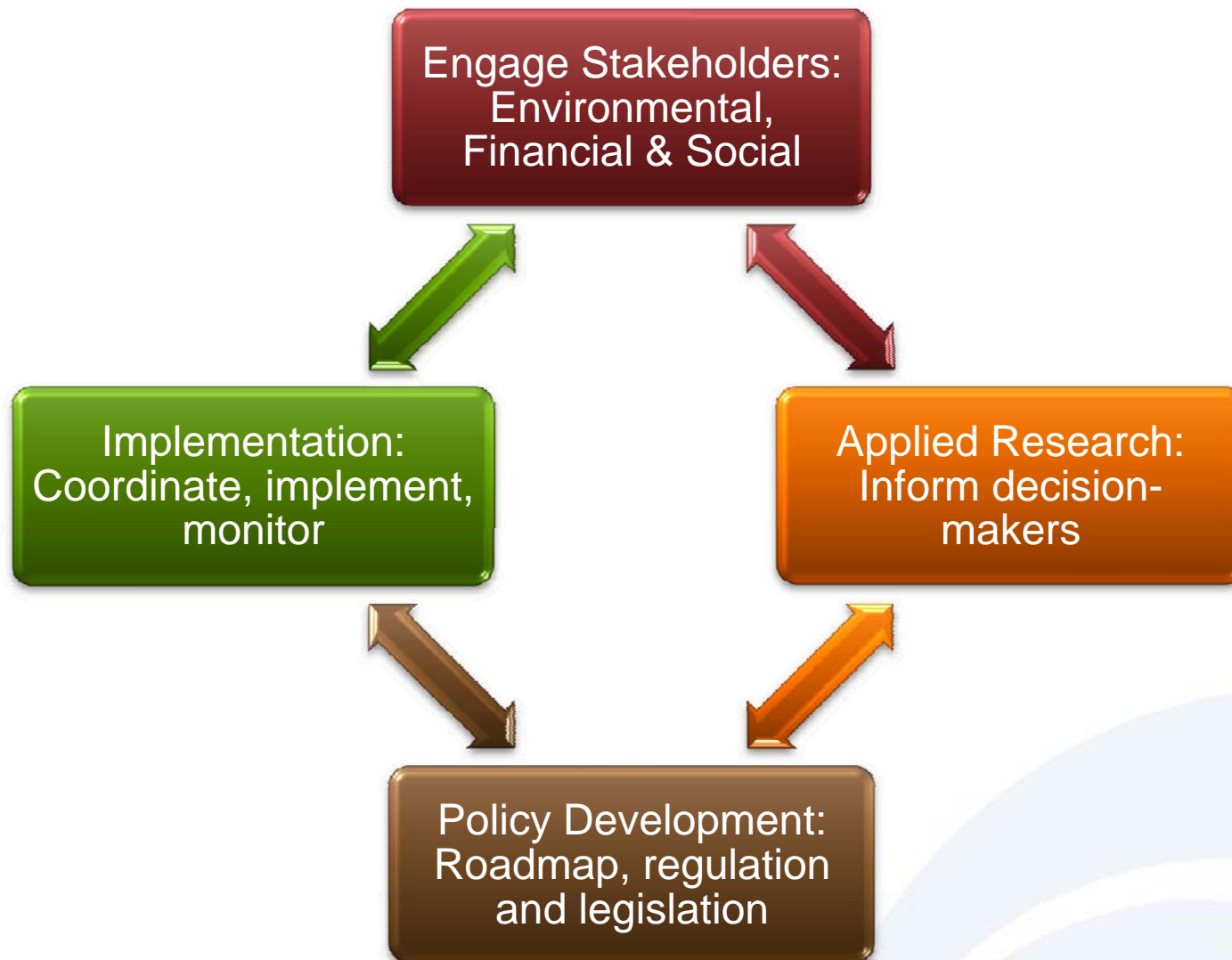
- Some of the proposed projects target the same countries.
- Interconnected grid systems require many support systems (legal, regulatory etc.) which have not yet been defined on a country by country basis.
- Further research needs to be undertaken not only considering the economical and technical viability, but also the social, environmental, legal and political factors.
- In many countries, required data are disorganized, dispersed, and closely held for personal, organizational, economic or political reasons, or simply (and very often) not available at all.

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# Defining the Way Forward: An Aggressive Integrated Approach is Required

# The Way Forward: An Aggressive Integrated Approach (AIA)

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## Energy Resource Assessment

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In keeping with the AIA, CARILEC is proposing to undertake an Energy Resource Assessment for the region which will:

Focus on forming strategic alliances with research institutions to further develop and build on existing research in the region.

This research will be multi-faceted and will consider technical, economical, social, environmental, policy and regulatory aspects.

Inform decision making by identifying the feasible and viable energy options by country and also as it pertains to regional interconnection.

## Conclusions

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Electric grid interconnections can be very complex legal undertakings, involving a variety of national, sub-national, and even international parties to the agreements required for planning, building, and operating power lines used to buy and sell electricity across borders.

- As such, binding legal agreements between countries (and between the countries and the outside lenders, if any, providing project financing), as well as the negotiation processes that produce the agreements, must be transparent and enforceable

The fair distribution of economic benefits among the nations involved in an interconnection, as well as among the groups within nations that are “stakeholders” in the interconnection, is an important element in ensuring that the political and social benefits of an interconnection are maximized, and that the political and social costs are kept low.

# Conclusions

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- Grid interconnections require a careful calculation of costs, benefits, and risks.
- Technical planning of a grid interconnection should be coordinated with economic, organizational, legal, and political aspects of a potential interconnection project from the outset of project consideration.

- An estimate of the significant environmental costs and benefits that will flow from a grid interconnection therefore requires a thorough and systematic study of all of the aspects of the interconnection, the electricity generation facilities feeding the interconnection, and the fuel chains feeding electricity generation, in all of the countries and areas within countries that may be affected by changes in energy sector activity or infrastructure brought about by the interconnection.

- Even with many different environmental impacts (costs and benefits) to consider in potentially several different geographic areas for each interconnection project, there are a number of general approaches that can be used in designing, planning, building and operating interconnections so as to increase net environmental benefits and reduce environmental costs and risks.



**CARILEC**  
An Association Of Electric Utilities

# THANK YOU ANY QUESTIONS/ COMMENTS?

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